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LESSON:

The Name Game

Summary: Students are introduced to the chemical perfluorooctanoic acid (PFOA) through the article "PFOA to Be Eliminated." Students then work in groups to draw the chemical structure of PFOA and derive the chemical formula based on its name, "perfluorooctanoic acid." Short Lesson—This lesson will take 20–30 minutes to implement.

EHP Article: "PFOA to Be Eliminated"
EHP Student Edition, July 2006, p. A217
http://www.ehponline.org/docs/2006/114-4/forum.html#beat

Objectives: By the end of this lesson, students should be able to:

1. describe the uses of PFOA and the potential health concerns;
2. list examples of the types of information provided by chemical nomenclature;
3. draw the chemical structure of PFOA based on its chemical name; and
4. write the chemical formula of PFOA based on its chemical name.

Class Time: 20–30 minutes

Grade Level: 10–12

Subjects Addressed: Chemistry, Biochemistry, Physical Science, Environmental Science

Prepping the Lesson (15 minutes)

INSTRUCTIONS:

1. Download the entire July 2006 *EHP Student Edition* at http://www.ehponline.org/science-ed/, or download just the article "PFOA to Be Eliminated" at http://www.ehponline.org/docs/2006/114-4/forum.html#beat.
2. Review the Background Information, Instructions, and Student Instructions.
3. Make copies of the Student Instructions.

MATERIALS (per student):

- 1 copy of *EHP Student Edition*, July 2006, or 1 copy of "PFOA to Be Eliminated," preferably in color
- 1 copy of the Student Instructions

VOCABULARY:

- chemical formula
- chemical structure
- perfluorooctanoic acid

BACKGROUND INFORMATION:

PFOA (perfluorooctanoic acid) is a surfactant, a water-soluble chemical that can emulsify oils or liquids in water, suspend small particles in water, and act as a wetting agent. PFOA is used to help make fluoroelastomers and fluoropolymers. Fluoroelastomers are synthetic, rubber-like materials ideal for high-performance aerospace and automotive applications or harsh environments. Fluoropolymers are flame-resistant, anticorrosive "super-plastics" that can withstand a wide range of high temperatures. Some fluoropolymers also have nonstick properties. This range of chemical properties of fluoropolymers and fluoroelastomers results in their extensive use in products such as nonstick cooking surfaces; high-speed computer chips; paints; printing inks; lubricants; stain prevention in carpets, clothing, and furniture; and food packaging to repel oils/grease. Fluoropolymers are also used in gear lubrication, power steering assemblies, brake assemblies, seatbelt guides, and windshield wiper blades.

Although PFOAs are meant to be "burned off" in the fluoropolymer and fluoroelastomer creation process, small amounts of PFOA sometimes remain. The extensive use of products with fluoropolymers and fluoroelastomers, combined with the

"staying ability" of PFOA (i.e., it does not biodegrade quickly), provides plenty of potential avenues for exposure to the substance.

The Resources section provides links to three informative chemical nomenclature websites, should you want to expand the lesson or provide additional information. The students should be able to complete the lesson with the instructions provided, even if they have limited knowledge about chemical nomenclature.

RESOURCES:

Environmental Health Perspectives, Environews by Topic page, http://ehp.niehs.nih.gov. Choose Chemical Exposures, Food Safety

Chemical nomenclature, University of Texas, http://courses.cm.utexas.edu/archive/Spring2002/CH301/McDevitt/Nomenclature.htm

IUPAC nomenclature of organic chemistry, Wikipedia, http://en.wikipedia.org/wiki/Organic_nomenclature

Nomenclature of carbohydrates, Queen Mary University of London, http://www.chem.qmul.ac.uk/iupac/2carb/app.html

Perfluorooctanoic acid, Dupont, http://www2.dupont.com/PFOA/en_US/index.html

Perfluorooctanoic acid, Wikipedia, http://en.wikipedia.org/wiki/Perfluorooctanoic_acid

Implementing the Lesson

INSTRUCTIONS:

1. Hand out copies of the Student Instructions and the article "PFOA to Be Eliminated."
2. Tell the students they are going to read a short article introducing them to a chemical called perfluorooctanoic acid (PFOA). The article could be read aloud as a class, in groups, or individually. Next, tell the class they are going to be divided into groups, which will compete against each other in a game to correctly draw the chemical structure of PFOA, as well as write the correct chemical formula, based on the name "perfluorooctanoic acid."
3. Divide the students into groups of three. Allow approximately 5–10 minutes for them to read the article and answer the two questions in Step 1. Encourage the students to provide clearly written and thorough answers.
4. If your students have experience with chemical nomenclature, they can begin immediately with the next part of the activity. Give the students 10–15 minutes (depending on your students' needs) to complete Steps 2 and 3. At the end of the timed period, ask a representative from each group to go to the board, draw the structure, and write the chemical formula. The groups should draw on the board at the same time so that no answers are changed based on the other groups' responses.
5. If your students have not been introduced to chemical nomenclature, you may need to briefly explain that chemists have a defined way of naming chemicals so that when they hear the name they can tell which elements make up the chemical and in what quantity or proportion, as well as how the elements are bonded together and arranged in the chemical. The Student Instructions also provide brief explanations.
6. As a class, review each group's answers to all of the questions. When reviewing the answers that are on the board, discuss similarities and differences between answers, and make corrections as needed. Provide the students with an opportunity to process the new information and demonstrate their understanding of the nomenclature system by self-correcting the work they will turn in.
7. You may consider providing points or a "reward" for the groups that got the answers correct.

NOTES & HELPFUL HINTS:

- If students get stuck with the anoic acid description, you could draw the end of the structure that contains the hydroxyl group and the double-bonded O (refer to the image in Step 2a in the Assessing the Lesson section).
- Some students may not know where to place the 15th fluoride atom. If this is the case, you could provide them with a hint like "one carbon has three fluorides attached to it."
- Students who have studied acids could illustrate which part of the molecule has the acid (hydrogen-donating) property. They should show the change in charges for the hydrogen and the PFOA molecule.

Aligning with Standards

SKILLS USED OR DEVELOPED:

- Classification
- Communication (oral, written)

- Comprehension (listening, reading)
- Critical thinking and response

SPECIFIC CONTENT ADDRESSED:

- Chemical nomenclature
- Chemical structure
- Chemical formulas
- Distribution of chemicals in the environment

NATIONAL SCIENCE EDUCATION STANDARDS MET:

Science Content Standards

Unifying Concepts and Processes Standard

- Systems, order, and organization
- Evidence, models, and explanation

Physical Science Standard

- Structure and properties of matter
- Interactions of energy and matter

Science in Personal and Social Perspectives Standard

- Personal and community health
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

Assessing the Lesson

Step 1: Students should write clear and thorough responses using their own words (i.e., do not copy directly from the article).

a) According to the information in the article, what factors do you think led the EPA to phase out the use of PFOA?

Animal studies have shown PFOA to cause cancer and birth defects. In addition, PFOA has been found in 95% of the American blood samples tested, and in the blood of other animal species.

b) PFOA is a man-made chemical (i.e., it is not naturally found in the environment). It is now being detected in the blood of humans, marine animals, and mammals such as polar bears that live relatively far from humans. What does this say about the stability of the chemical, and why is that a concern? Be sure to explain your answer.

Since PFOA does not occur naturally and is found in so many species, even those that are fairly isolated from humans, that indicates that PFOA is stable in the environment, and does not break down (or biodegrade) quickly. This is a concern because:

- the longer a chemical remains in the environment, the more it can accumulate in the environment as the chemical continues to be used;
- the chemical could bioaccumulate—i.e., be passed up through the food chain, resulting in high concentrations in larger animal species; and
- the greater the exposure to the chemical, the higher the potential for adverse health effects to occur, if the chemical can cause adverse health effects.

Students may have any one of the above responses. There may be additional correct or logical responses that are not included here. To reinforce the use of accurate language, have students rewrite any answers that are unclear or inaccurate. This includes having students change absolute words like "proves" to words like "could," "may," or "potentially."

Step 2: a) Working with your group, draw the chemical structure of **perfluorooctanoic acid** based only on the name. NOTE: Depending on the level of experience your students have with chemical nomenclature, they can either show or not show the carbon atoms in the structure. If the students leave out the carbon atoms (as shown in the image below) make sure they understand that a carbon exists at each line intersection, with one at the end of the molecule bonded with the O and the OH (for a total of 8 carbons).

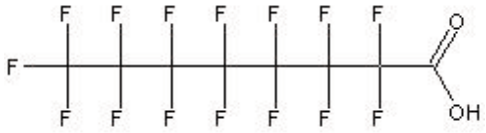

Image courtesy of Wikipedia

Step 3: a) Write the chemical formula for PFOA.

$C_8HF_{15}O_2$

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Give us your feedback! Send comments about this lesson to ehpscienceed@niehs.nih.gov.

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STUDENT INSTRUCTIONS: The Name Game

Step 1: Read the article "PFOA to Be Eliminated" and answer the following questions. Write clear and thorough responses using your own words (i.e., do not copy directly from the article).

a) According to the information in the article, what factors do you think led the EPA to phase out the use of PFOA?

b) PFOA is a man-made chemical (i.e., it is not naturally found in the environment). It is now being detected in the blood of humans, marine animals, and mammals such as polar bears that live relatively far from humans. What does this say about the stability of the chemical, and why is that a concern? Be sure to explain your answer.

Step 2: Read the information below and follow the instructions.

Perfluorooctanoic acid—what a mouthful! No wonder they call it PFOA. Chemical names can get long and complex sounding, but they are long for a reason. Chemists want to know something about the chemical almost instantaneously. Is it organic or inorganic? Is it acidic? Is it a salt? Is it an alcohol?

To get this "instantaneous" information, chemists have developed a naming system where each piece of the name says something about the chemical: the elements present in the chemical, the bonding structure, and where the elements reside in the chemical (e.g., at the end or in the middle). The name also tells us something about its properties (e.g., acidic, basic, solvent, etc.).

a) Working with your group, draw the chemical structure of **perfluorooctanoic acid** based only on the name. Use the following clues to help you. Be prepared to share your drawing with the class.

per = 2 oxygens (these are located in the anoic acid part of the molecule).

fluoro = the element fluoride is in the chemical. In PFOA there are 15 fluoride atoms bonded to the carbons.

oct = 8 carbons form the "backbone" of the molecule.

anoic acid = refers to carboxylic acid (commonly called acetic acid, which is the chemical that makes vinegar taste sour). Shaped like a less-than sign (<) with a carbon at the point of the "<", anoic acid has one oxygen double-bonded to the carbon for one arm of the "<". On the other arm of the "<" is a hydroxyl group (OH) bonded to the same carbon. HINT: The anoic acid is at one end of the PFOA and it does not matter whether the OH is on the top or the bottom of the "<".

Step 3: The chemical formula tells us the elements that make up the chemical and how many there are of each element. For example, water has 2 hydrogen atoms and 1 oxygen atom represented by the formula H_2O. Table sugar, or sucrose (the ending –ose tells us it is a sugar), has 12 carbon atoms, 22 hydrogen atoms, and 11 oxygen atoms, represented by the formula $C_{12}H_{22}O_{11}$.

a) Write the chemical formula for PFOA.

National Institute of Environmental Health Sciences
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